# TITLE OF THE INVENTION

## POSITION DETECTING METHOD AND APPARATUS

5 ### FIELD OF THE INVENTION

This invention relates to a position detectingtechnique for detecting a position of a mark.

10 ### BACKGROUND OF THE INVENTION

A mark imaging method in an ordinary exposure apparatus for manufacturing semiconductors will be described with reference to Fig. 7. Shown in Fig. 7

15 are a reticle R, a wafer W that is a substrate to be exposed, a projection optical system 1 in which the optic axis is the z axis, an optical system S for imaging marks that are to be observed, an illumination unit 2 for imaging the marks, a beam splitter 3,

20 optical systems 4 and 5 for forming an image, an image sensing unit 6, an A/D converter 7, an integrating unit 8, an image processing unit 9, a stage driving unit 10, a stage 11 that is movable in three dimensions, and a position measuring unit 12, such as

25 an interferometer, for measuring stage position.

Mark imaging in the exposure apparatus having the above-described structure is performed through the

following procedure:  First, the reticle R is moved by
a reticle-stage moving unit (not shown) to a position
at which a reticle mark RM can be observed.  Similarly,
the stage 11 is moved to a position at which it is

5    possible to observe an observation mark WM on the
wafer W.  Initially, the wafer mark WM is illuminated
by light flux, which is emitted by the illumination
unit 2, via the beam splitter 3, reticle mark RM and
projection optical system 1.  Light flux reflected

10   from the wafer mark WM reaches the beam splitter 3
again via the projection optical system 1 and reticle
R.  The light flux that has arrived from the
projection optical system 1 is reflected by the beam
splitter 3 and forms an image RM of the reticle mark

15   and an image WM of the wafer mark on the image sensing
surface of the image sensing unit 6 via the image
forming optical system 5.

Fig. 2A illustrates an example of the observation
marks whose images have been formed on the image

20   sensing surface in the above description.  The reticle
mark RM and the wafer mark WM each comprise a
plurality of identically shaped patterns.  The reticle
mark and the wafer mark have a mark pitch equivalent
to a certain fundamental spatial frequency.  The image

25   sensing unit 6 converts the images of the marks formed
on the image sensing surface into electric signals
(photoelectric conversion).  The A/D converter 7

subsequently converts the output of the image sensing

unit 6 to a two-dimensional digital signal sequence.

The integrating unit 8 in Fig. 7 executes

integration processing along the direction Y of an

5    area WP of the kind shown in Fig. 2A and converts the

two-dimensional signal to a one-dimensional digital

signal sequence $S0(x)$, as shown in Fig. 2B. On the

basis of the digital signal sequence $S0(x)$ obtained by

the conversion, the image processing unit 9 uses means

10   such as pattern matching or calculation of center of

gravity to measure the center positions of the reticle

and wafer marks and measure their relative positions.

The above-described method of detecting mark

position is one that is extremely useful in a position

15   detecting apparatus that requires accurate detection

of mark position. In the above example of the prior

art, however, the signal is a discrete sequence owing

to the A/D conversion for the purpose of processing

the electric signal and, hence, the detected mark

20   positions also are discrete values. The influence of

this can no longer be neglected as the need for

greater position detection accuracy grows.

To deal with this, the specifications of Japanese

Patent Application Laid-Open Nos. 3-282715 and 10-

25   284406 disclose techniques for converting discrete

sequence signals to signals in a spatial frequency

domain by an orthogonal transform and measuring mark

position based upon the phase of mark-specific spatial frequency component, thereby making it possible to detect position from discrete sequence signals in highly accurate fashion.

5       However, in a case where the art disclosed in the specifications of Japanese Patent Application Laid-Open Nos. 3-282715 and 10-284406 is utilized, position must be measured mark by mark in order to measure the positions of both the reticle mark RM and wafer mark

10  WM.  In other words, a processing window must be set separately at the two areas of reticle mark RM and wafer mark WM, and the orthogonal transform, which places a burden on processing, must be performed twice. The problem that arises is a decline in throughput.

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## SUMMARY OF THE INVENTION

        An object of the present invention is to realize a reduction in time for  mark position detection that

20  uses an orthogonal transform.

        According to one aspect of the present invention, there is provided a a position detecting method comprising steps of: sensing an image of first and second marks; orthogonal transforming a signal

25  obtained in the sensing step; and calculating each position of the first and second marks based on a phase of a corresponding frequency component obtained

in the transform step.

Further, according to another aspect of the present invention, there is provided a position detecting apparatus comprising: a sensing unit which
5    senses an image of first and second marks; a transform unit which orthogonal transforms a signal obtained by the sensing unit; and a calculation unit which calculates each position of the first and second marks based on a phase of a corresponding frequency
10    component obtained by the transform unit.

Other features and advantages of the present invention will be apparent from the following description taken in conjunction with the accompanying drawings, in which like reference characters designate
15    the same or similar parts throughout the figures thereof.


BRIEF DESCRIPTION OF THE DRAWINGS


20    The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

25    Fig. 1 is a block diagram for describing the positioning-related structure of an exposure apparatus

for manufacturing semiconductors according to a first embodiment of the present invention;

Figs. 2A and 2B are diagrams illustrating a general example of images of observation marks on an image sensing surface and a periodic pattern signal obtained as a result of these observation marks, respectively;

Fig. 3A and 3B are diagrams illustrating an example of images of observation marks on an image sensing surface and a periodic pattern signal obtained as a result of these observation marks, respectively, in the first embodiment;

Fig. 4 is a diagram illustrating a spatial frequency domain obtained by orthogonal transforming the periodic pattern signal waveform shown in Fig. 3A;

Fig. 5 is a diagram illustrating an example of images of observation marks on an image sensing surface according to a second embodiment of the invention;

Fig. 6A and 6B are diagrams illustrating an example of images of observation marks on an image sensing surface and a periodic pattern signal obtained as a result of these observation marks, respectively, in a third embodiment of the present invention;

Fig. 7 is a block diagram for describing the positioning-related structure of a conventional exposure apparatus for manufacturing semiconductors;

Fig. 8 is a flowchart for describing the procedure of signal processing according to the first embodiment; and

Fig. 9 is a diagram useful in describing the flow

5   of device manufacture.


DESCRIPTION OF THE PREFERRED EMBODIMENTS


Preferred embodiments of the present invention

10  will now be described in detail in accordance with the accompanying drawings.

<First Embodiment>

An example in which positioning according to the present invention is applied to an exposure apparatus

15  for semiconductor manufacture is illustrated below. Shown in Fig. 1 are the reticle R, the wafer W that is the substrate to be exposed, the projection optical system 1 in which the optic axis is the z axis, the optical system S for imaging marks to be observed, the

20  illumination unit 2 for imaging the marks, the beam splitter 3, the optical systems 4 and 5 for forming an image, the image sensing unit 6, the A/D converter 7, the integrating unit 8, the image processing unit 9, the stage driving unit 10, the stage 11 that is

25  movable in three dimensions, the position measuring unit 12, such as an interferometer, for the position of the stage 11, an orthogonal transform unit 13, a

phase calculation unit 14 and a position calculation unit 15. The procedure for mark imaging and position measurement by the positioning arrangement of this embodiment constructed as set forth above will now be

5  described.

First, the reticle R is moved by a reticle-stage moving unit (not shown) to a position at which the reticle mark RM can be observed. Similarly, the stage 11 is moved to a position at which it is possible to

10  observe the observation mark WM on the wafer W.

Next, light flux for illuminating the observation marks is emitted by the illumination unit 2. It should be noted that the illumination unit 2 may just as well serve as an illumination unit for measuring

15  focal point. The light flux emitted from illumination unit 2 illuminates the wafer mark WM via the beam splitter 3, reticle mark RM and projection optical system 1. Light flux reflected from the wafer mark WM reaches the beam splitter 3 again via the projection

20  optical system 1 and reticle R. The light flux that has arrived is reflected by the beam splitter 3 and forms the image RM of the reticle mark and the image WM of the wafer mark on the image sensing surface of the image sensing unit 6 via the image forming optical

25  system 5.

Fig. 3A illustrates an example of images of the observation marks on the image sensing surface. The

reticle mark RM and the wafer mark WM each comprise a
plurality of identically shaped patterns.  In Fig. 3A,
the image of wafer mark WM is arranged to fall between
the images of reticle marks RM, though an arrangement

5    in which the reticle mark RM falls between the wafer
marks WM may be adopted.  However, it should be noted
that the image of the reticle mark RM is disposed on
the image sensing surface with a line width and pitch
that differ from those of the wafer mark WM on the

10   image sensing surface.  Pitch PR of the reticle mark
and pitch PW of the wafer mark are related by the
equation $PW \neq mPR$ (where m is an arbitrary integer).
Further, in a case where processing is executed upon
inserting the wafer mark WM between the reticle marks,

15   as shown in Fig. 3A, span SR of the reticle marks RM
bracketing the wafer mark WM is expressed by the
equation $SR = nSR$ (where n is an arbitrary integer).
(It should be noted that in a case where a mark is not
inserted between marks, positioning is performed in

20   such a manner that the mark positions obtained will be
spaced apart a prescribed distance rather than be made
to coincide.)

The group of marks described above is imaged and
subjected to photoelectric conversion by the image

25   sensing unit 6.  The A/D converter 7 subsequently
converts the output of the image sensing unit 6 to a
two-dimensional digital signal sequence.  The

integrating unit 8 in Fig. 1 executes integration

processing along the direction Y of the area WP of the

kind shown in Fig. 3A and converts the two-dimensional

signal to a one-dimensional digital signal sequence

5    S0(x), as shown in Fig. 3B.  The mark positions are

then calculated by processing the digital signal

sequence, which has been obtained by the conversion,

by the method set forth in the specifications of

Japanese Patent Application Laid-Open Nos. 3-282715

10    and 10-284406.

        A case where the mark-position calculation method

disclosed in the specification of Japanese Patent

Application Laid-Open No. 10-284406 is applied will

now be described.

15        Fig. 8 is a flowchart for describing the

procedure of signal processing according to this

embodiment.  In Fig. 8, a periodic pattern is

generated at step S1.  More specifically, a one-

dimensional discrete signal sequence having

20    periodicity of the kind shown in Fig. 3B is generated

by the integrating unit 8 and supplied to the

orthogonal transform unit 13.

        Next, at step S2, the orthogonal transform unit

13 applies orthogonal transform processing to the

25    signal that enters from the integrating unit 8.  Here

a well-known orthogonal transform such as a discrete

Fourier transform is applied to the input signal to

convert the signal to a spatial frequency domain. For
example, in a case where a discrete Fourier transform
is used as the orthogonal transform, values in the
spatial frequency domain can be obtained by the

5   following transformation formulae:

$$Xr(f) = \sum_{n=-N/2}^{n=N/2} x(xo + n)\cos(-2\pi nf / N) \qquad \ldots (1)$$

$$Xi(f) = \sum_{n=-N/2}^{n=N/2} x(xo + n)\sin(-2\pi nf / N) \qquad \ldots (2)$$

In Equations (1) and (2) above, x represents an
input signal sequence, Xr the real-number part of a

10  spatial frequency component, Xi the imaginary-part of
a spatial frequency component, N the processing width
of the discrete Fourier transform, xo a position at
which phase is detected at the center of the
processing range of the discrete Fourier transform,

15  and f a frequency of interest, which is the frequency
of the spatial frequency component sought.

In the orthogonal transform, the values at all
frequencies are obtained and the frequency for which
power is maximized is selected. Fig. 4 illustrates

20  the spectrum distribution after the application of the
orthogonal transform. Since the pitch of the reticle
mark RM and that of the wafer mark WM differ, the
distribution has peaks at spatial frequencies fR, fW
that differ from each other. The phases of the

25  spatial frequencies fR, fW corresponding to the peaks
are obtained by the phase calculation unit 14 at step

S3 and the mark positions are calculated by the position calculation unit 15 at step S4.

First, the phase calculation unit 14 uses the following well-known Equation (3) to calculate the phase θ of a spatial frequency component for which a pattern to be detected in the spatial frequency domain appears uniquely:

$$\theta = \arctan\left(\frac{Xi(f)}{Xr(f)}\right) \qquad \ldots (3)$$

Here the phase θ is obtained with regard to a case where f is fR and with regard to a case where f is fW.

Next, the position calculation unit 15 uses Equation (4) below to calculate mark position d from the phase θ obtained by the phase calculation unit 14. It should be noted that the two mark positions, namely the reticle mark position and wafer mark position, are calculated in association with the two phases obtained by the phase calculation unit 14.

$$d = xo + \left(\frac{\theta N}{\pi f}\right) \qquad \ldots (4)$$

This equation is the result of adding the amount of phase advance obtained when the periodic pattern signal advances by the amount of the phase θ to xo. Accordingly, the relative positions between the two marks, namely the reticle mark RM and the wafer mark WM, can be detected and the positioning of the reticle and wafer can be carried based upon the results of detection.

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Thus, in accordance with the first embodiment as described above, the reticle mark RM and the wafer mark WM are disposed at mutually different line widths and pitches, it is so arranged that the pitch PR of

5   the reticle mark and pitch PW of the wafer mark will satisfy the inequality PW $\neq$ mPR (where m is an arbitrary integer), and the discrete sequence signal is orthogonal transformed, whereby the fundamental spatial frequency component of each mark can be

10  obtained by executing orthogonal transform processing a single time and the position of each mark can be found accurately from the phase of the fundamental spatial frequency component corresponding to each mark. In other words, the relative positions of the reticle

15  mark RM and wafer mark WM can be obtained by executing orthogonal transform processing a single time.  As a result, highly precise detection of position is possible and the problem relating to throughput does not arise.

20      Further, in accordance with the above-described technique, mark position is detected by taking note of the periodicity of the signal sequence.  As a result, there is little susceptibility to effects of noise that may be contained in the signal.

25      <Second Embodiment>

A second embodiment relating to positioning of a wafer and reticle in an exposure apparatus for

semiconductor manufacture is illustrated below. In

the first embodiment, position is detected from marks

arrayed in one dimension and therefore position can be

only be calculated in one direction from one mark. In

5   the second embodiment, it is so arranged that position

detection corresponding to two directions can be

performed using a single mark. It should be noted

that the structure of the apparatus relating to

positioning is similar to that of the first embodiment

10  (see Fig. 1) and need not be illustrated and described

again.

Fig. 5 is a diagram illustrating an example of

observation marks whose images are formed on the image

sensing surface of the image sensing unit 6. The

15  marks employed in the second embodiment are obtained

by disposing reticle mark RM composed of a plurality

of identically shaped patterns and reticle mark WM

composed of a plurality of identically shaped patterns.

Furthermore, identically shaped marks are disposed in

20  two mutually orthogonal directions in such a manner

that measurement along the x, y directions can be

performed from an image obtained by a single image

sensing operation.

As shown in Fig. 5, the images of the reticle

25  mark RM and the wafer mark WM are disposed on the

image sensing surface at mutually differ line widths

and pitches, and it is so arranged that the pitch PR

of the reticle mark and pitch PW of the wafer mark are related by the equation PW $\neq$ mPR (where m is an arbitrary integer).  Further, it is so arranged that the span SR of the reticle marks RM is expressed by

5   the equation SR = $n_1$PR (where $n_1$ is an arbitrary integer), and it is so arranged that span SW of the wafer marks WM is expressed by the equation SW = $n_2$PW (where $n_2$ is an arbitrary integer).  Even though the images of the marks thus disposed on the image sensing

10  surface are spaced apart by the respective spans SR, SW, there is no influence upon the orthogonal transform because the phases are equal, and measurement of the mark positions can be performed through a method similar to that described in the

15  first embodiment.

     <Third Embodiment>

     A third embodiment relating to positioning of a wafer and reticle in an exposure apparatus for semiconductor manufacture is illustrated below.  A

20  very high precision is required for aligning a wafer and a reticle, and it is required that the positions of the wafer mark and reticle mark be found in highly accurate fashion.  Accordingly, in the third embodiment, at least either the wafer mark or the

25  reticle mark has mark pitches exhibiting different fundamental spatial frequencies, and the position of each mark is detected with high precision by applying

the position detection method described in the first

and second embodiments.  More specifically, in the

first and second embodiments, the positions of the

reticle mark and wafer mark are obtained and their

5  relative positions are calculated.  In the third

embodiment, however, a mark of a different fundamental

spatial frequency is provided in one mark (e.g., the

reticle mark) and it is so arranged that calculation

of coarse and fine positions can be calculated by

10  applying an orthogonal transform a single time.  It

should be noted that the structure of the apparatus

relating to positioning is similar to that of the

first embodiment (see Fig. 1) and need not be

illustrated or described again.

15      Figs. 6A and 6B are diagrams illustrating an

example of observation marks whose images are formed

on the image sensing surface of the image sensing unit

6 in the third embodiment.  An observation mark (wafer

mark) according to the third embodiment is composed of

20  a plurality of identically shaped patterns.  As shown

in Fig. 6A, the image of wafer mark WM1 is disposed on

the image sensing surface with a line width and pitch

that differ from those of a wafer mark WM2 on the

image sensing surface.  It is so arranged that pitch

25  PW1 and pitch PW2 of the wafer marks are related by

the equation $PW1 \neq mPW2$ (where m is an arbitrary

integer).  If calculation of mark position is

performed by a method similar to that of the first

embodiment using such marks, xo is decided upon

obtaining the coarse position of the wafer mark at WM1

having the coarse pitch, then the position of WM2

5    having the finer pitch is calculated and xo is

corrected, whereby a more accurate mark position can

be obtained.

The third embodiment has been described with

regard to a wafer mark.  However, similar processing

10   may be executed by disposing marks having a different

mark pitch of the above kind also on the reticle side.

In each of the above embodiments, it is also

possible to utilize a periodic pattern included in

actual elements (actual circuit patterns) as a

15   periodic pattern composed of a group of marks.

The main characterizing features relating to each

of the foregoing embodiments may be summarized as

follows:

In a mechanism that performs position detection

20   based upon alignment marks comprising a plurality of

repeating patterns, first a signal waveform conforming

to the repetition of the plurality of patterns of the

alignment marks (Figs. 3A, 3B and Figs. 6A, 6B) is

generated (image sensing unit 6, A/D converter 7 and

25   integrating unit 8).  The signal waveform generated is

subjected to an orthogonal transform by the orthogonal

transform unit 13 to generate a spatial frequency

domain signal, and a plurality of peaks corresponding to different fundamental spatial frequencies are detected based upon peak positions in (power) spectrum signal according to the spatial frequency domain

5    signal (fW, fR, Fig. 4).  The phase calculation unit 14 then obtains the phases regarding the fundamental spatial frequency component corresponding to each of the plurality of peaks detected, and the position calculation unit 15 calculates pattern position based

10   upon the phases obtained.

In particular, with regard to generation of the signal waveform in the image sensing unit 6, A/D converter 7 and integrating unit 8 in the first and second embodiments, there is generated a signal

15   waveform (Fig. 3A) that corresponds to alignment marks obtained by observing an alignment mark (RM), which is provided on the surface of a first object, and an alignment mark (WM), which is provided on the surface of a second object, in such a manner that these

20   alignment marks combine.  The position of the alignment mark provided on the surface of the first object and the position of the alignment mark provided on the surface of the second object are calculated by the orthogonal transform unit 13, phase calculation

25   unit 14 and position calculation unit 15.

It should be noted that, it is preferred that the different fundamental spatial frequencies differ from

each other by an integral multiple.

Further, in the third embodiment, a coarse
position of an alignment mark is obtained based upon a
phase calculated with regard to a low fundamental

5      frequency (WM1 in Fig. 6), and a fine position is
calculated upon correcting the coarse position based
upon a phase calculated with regard to a higher basic
fundamental frequency (WM2 in Fig. 6A).

Further, in the first and second embodiments,

10     there are supplied a first substrate (reticle R)
having an alignment mark (RM) comprising a plurality
of patterns that repeat at intervals PR, and a second
substrate (wafer W) having an alignment mark (WM)
comprising a plurality of patterns that repeat at

15     intervals PW, where PR ≠ mPW holds (and m is an
integer).  A signal corresponding to the row of the
plurality of patterns (Fig. 3B) is generated from
combined alignment marks (Fig. 3A, Fig. 5) obtained by
simultaneously observing the alignment marks on the

20     first and second substrates.  The generated signal is
subjected to an orthogonal transform in the orthogonal
transform unit 13 to obtain a spatial frequency domain
signal.  Two peaks (fW, fR) corresponding to the
fundamental frequencies conforming to the intervals PR

25     and PW are detected based upon peak position in this
spatial frequency domain signal.  The phase
calculation unit 14 then obtains the phases regarding

the fundamental spatial frequencies corresponding to the two peaks detected, and the position calculation unit 15 calculates the positions of the positioning patterns on the first and second substrates based upon

5    the phases obtained.

Further, in accordance with the first embodiment, the alignment mark on the first substrate has a portion in which patterns disposed over an interval SR = nPR (where n is an integer) is located in a row of

10   the patterns that repeat at the intervals PR, and the combined alignment marks (Fig. 3A) are such that a plurality of patterns on the second substrate are disposed between the patterns spaced apart by the interval SR.

15   Further, in accordance with the second embodiment, the alignment mark on the first substrate has a portion in which patterns are disposed over an interval SR = nPR (where n is an integer), and two of these alignment marks are provided (Fig. 5) so as to

20   intersect orthogonally in the portion of interval SR. The alignment mark on the second substrate has a portion in which patterns are disposed over an interval SW = kPW (where k is an integer), and two of these alignment marks are provided (Fig. 5) so as to

25   intersect orthogonally in the portion of interval SW. The combined alignment marks are such that the alignment mark on the second substrate is disposed in

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a space formed by the portion having the interval SR

of the alignment mark on the first substrate (Fig. 5).

A process for manufacturing a semiconductor

device such as a microdevice utilizing the exposure

5   apparatus set forth above will now be described.

Fig. 9 is a diagram illustrating the overall flow

of a process for manufacturing the semiconductor

device.   The circuit for the semiconductor device is

designed at step S1 (circuit design).   A mask is

10  fabricated at step S2 (mask fabrication) based upon

the circuit pattern designed.

Meanwhile, a wafer is manufactured using a

material such as silicon at step S3 (wafer

manufacture).   Using the above-described mask and

15  wafer, the above-described exposure apparatus forms

the actual circuit on the wafer utilizing lithography

at step S4 (wafer process), which is also referred to

as "pre-treatment".   A semiconductor chip is obtained,

using the wafer fabricated at step S4, at step S5

20  (assembly), which is also referred to as "post-

treatment".   This step includes steps such as assembly

(dicing and bonding) and packaging (chip

encapsulation).   The semiconductor device fabricated

at step S5 is subjected to inspections such as an

25  operation verification test and durability test at

step S6 (inspection).   The semiconductor device is

completed through these steps and then is shipped at

step S7.

The wafer process of step 4 above has the following steps: An oxidizing step of oxidizing the surface of the wafer; a CVD step of forming an

5 insulating film on the wafer surface; an electrode forming step of electrodes on the wafer by vapor deposition; an ion implantation step of implanting ions in the wafer; a resist treatment step of coating the wafer with a photoresist; an exposure step of

10 transferring the circuit pattern to the wafer by the above-described exposure apparatus after the resist treatment step; a developing step of developing the wafer exposed at the exposure step; an etching step of etching away portions other than the photoresist

15 developed at the developing step; and a resist removing step of removing unnecessary resist left after etching is performed. Multiple circuit patterns are formed on the wafer by implementing these steps repeatedly.

20 In accordance with the present invention, as described above, it is possible to raise the speed of mark position detection that uses an orthogonal transform.

As many apparently widely different embodiments

25 of the present invention can be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited to the

specific embodiments thereof except as defined in the

appended claims.